FINAL REPORT: Relationship between Physical and Biological properties on the Microscale: A cross-comparison between Differing Coastal Domains

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LONG-TERM GOALS

We seek a more complete and fundamental understanding of the hierarchy of processes that transfer energy and momentum from large scales, feed the internal wavefield, and ultimately dissipate through turbulence. This cascade impacts the acoustic, optical, and biogeochemical properties of the water column, and feeds back to alter the larger scale circulation. Studies within the **Ocean Mixing Group** at OSU emphasize observations, innovative sensor / instrumentation development and integration, and process-oriented internal wave and turbulence modeling for interpretation.

OBJECTIVES

We seek to understand the processes that attenuate optical and acoustic signals in the upper ocean. Our specific objectives address the mechanisms that form and maintain steep gradients and thin layers of particulate concentration.

APPROACH

Over 60000 microstructure profiles were obtained by the OSU Ocean Mixing Group during these three field experiments (COAST, RISE, SW06). Considerable analysis of physical oceanographic properties has been completed on these profiles, as reflected in several recent publications (e.g., Moum et al. 2003, Nash and Moum 2005, Perlin et al. 2005, Shroyer et al. 2010a, 2010b, 2011). Each dataset contains multiple, extended sequences of microstructure profiles closely spaced in time and horizontal distance, frequently yielding horizontal resolution of O(200m) and temporal resolution of O(5mins) during each extended sequence. This coverage permits resolution of temporally or spatially coherent plankton layers that may be forced by a wide range of processes, from high frequency internal waves to velocity gradients along coastal fronts, or layers that are subject to intermittent overturning and small-scale turbulent mixing.

Here, density and turbulent microstructure data were used to characterize the properties and physical setting of fluorescent layers observed over the New Jersey shelf for the following analyses:

- utilize existing datasets of Chameleon profiles (upwelling domain over Oregon shelf, CR plume, NJ shelf) for persistent layers of particulate matter (defined by turbidity or chlorophyll);

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- quantify the relationship between layer characteristics (vertical gradients, thickness, relationship to pycnocline) and physical descriptors (stratification, shear, TKE dissipation, turbulent mixing);
- quantify the spatial patterns, temporal persistence and coherence of the physical descriptors to assess how these permit both persistent layers and regions void of thin layers;
- compare these relationships as expressed within the upwelling system, buoyant plume, and NJ shelf;
- relate regional layer characteristics to local and regional forcing (wind, current jets, etc);
- examine results in the context of recent theoretical developments about layer formation and maintenance.

WORK COMPLETED

Emily Shroyer primarily conducted the analyses detailed in the list outlined in the "Approach" section.

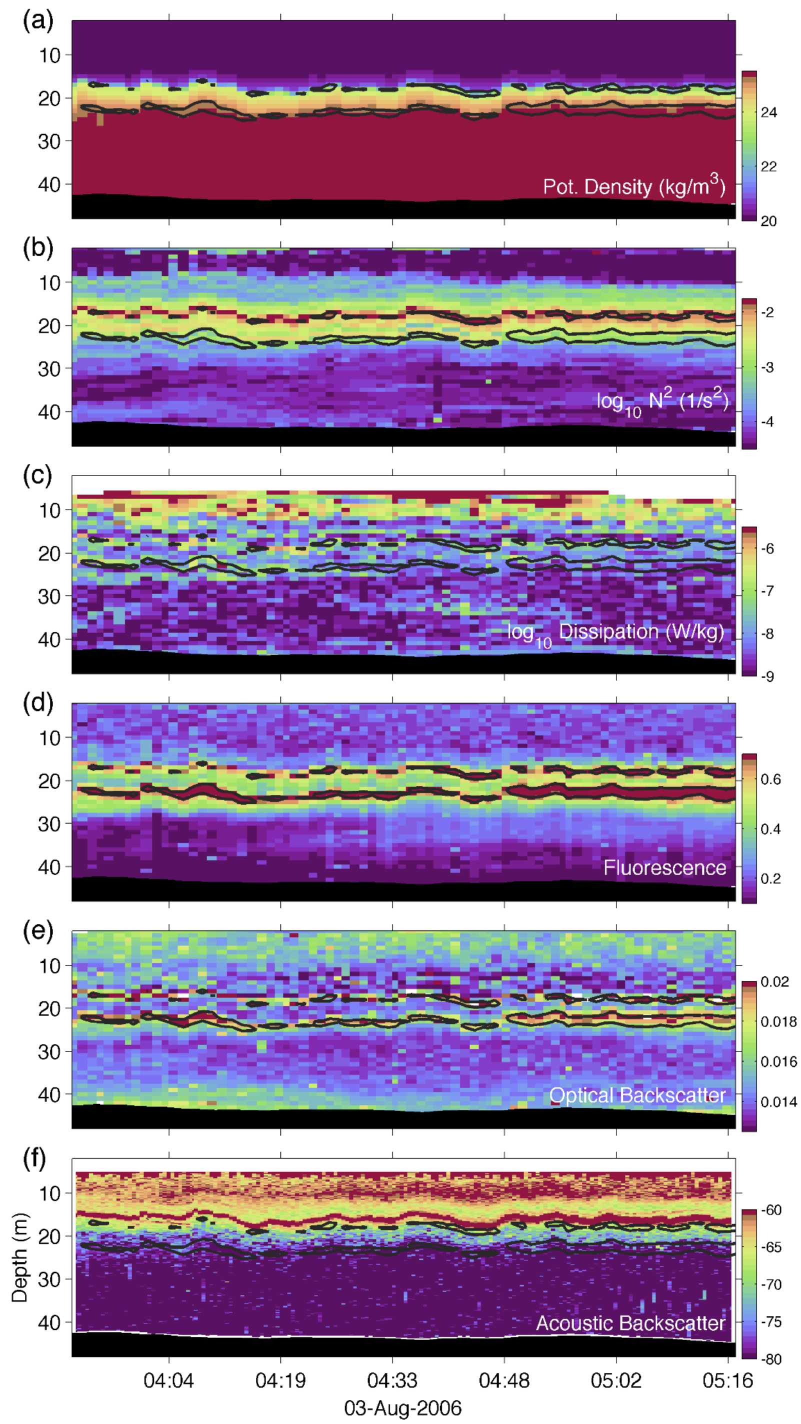


Figure 1: Temporal structure typical of the layering on the NJ coast. Optics, acoustics, turbulence, and the mean structure these and hundreds of other thin layers were examined in this analysis. Example shows (a) potential density, (b) stratification, (c) TKE Dissipation, (d) Fluorescence, (e) optical backscatter, and (f) acoustic backscatter. Fluorescent layers are contoured in each panel for reference.

RESULTS

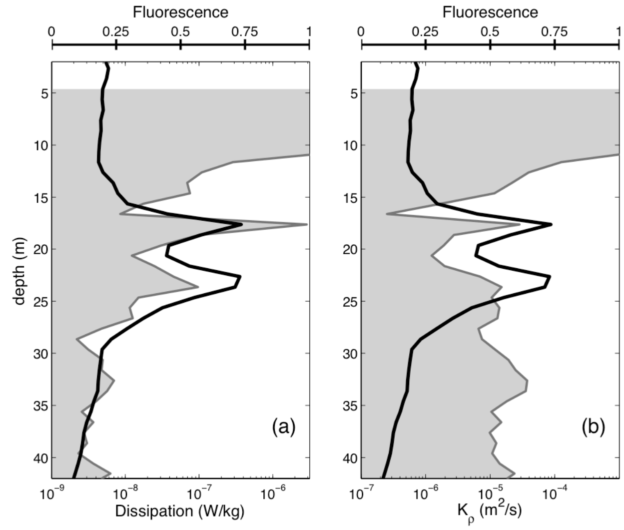
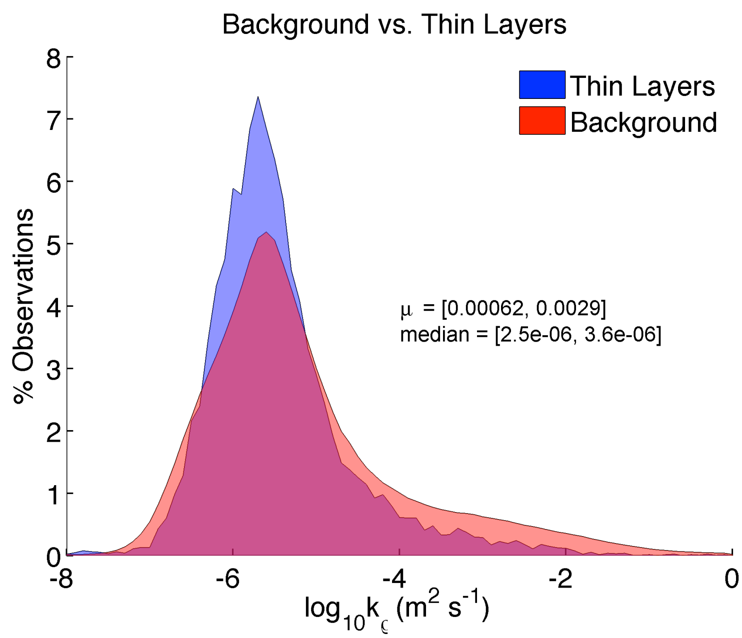


Figure 2: (a) TKE dissipation rate and (b) diffusivity (shading) and their relationship to normalized fluorescence (black line) for data presented in Fig. 1 and averaged along isopycnals.

Observed layers were differentiated into two types by their vertical position in the water column, fluorescence intensity, and possibly community composition or cell condition as indicated by the measured differences in the ratio of fluorescence to optical backscatter. Both layer types were associated with stratification gradients. However, the turbulent mixing environment for the two layer types differed significantly. Shallow layers were located in regions of relatively strong gradients and were exposed to strong mixing events within the surface mixed layer. Consequently, turbulent mixing of buoyancy and presumably nutrients may have played an important role in maintaining shallow layers. In contrast, weak gradients and mixing indicate that turbulent processes may have been less critical for deep layers. More generally, both shallow and deep layers were located in regions of low median and high mean turbulent kinetic energy dissipation, i.e., regions of rare yet intense mixing events. This work highlights the need to understand the detailed statistics of mixing at time and vertical scales relevant to thin layers, more specifically the need to discern the time history of mixing of the fluid that composes layers.   Results are detailed in Shroyer et al, 2013

Figure 3: Histogram showing the statistical differences in mixing within layers vs. outside of layers. While layers have similar median diffusivities, absent from layers are the extreme events that dominate mixing in the mean.



SIGNIFICANCE

Attenuation of light and sound propagation in the upper ocean is tightly linked to the patterns of vertical distribution of particulate matter (primarily detritus, phytoplankton, and zooplankton). Local maxima in these distributions frequently occur within the euphotic zone, and are often concentrated within depth intervals that are less than 1-2m thick (e.g., Dekshenieks et al. 2001, Cowles 2004). Steep vertical gradients of stratification and/or shear that often exist at the boundaries of these plankton layers, and which are implicated in their formation and maintenance (Benoit-Bird et al, 2013, Shroyer et al, 2013, Stacey et al. 2007, Birch et al. 2008) are of particular interest for acoustic and optical propagation.

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